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Full Length Research Paper

Response of potato (*Solanum tuberosum* L.) to different rates of nitrogen and phosphorus fertilization on vertisols at Debre Berhan, in the central highlands of Ethiopia

Zelalem A., Tekalign T. and Nigussie D.

Haramaya University, College of Agriculture, Department of Plant Sciences, P. O. Box 138, Dire Dawa, Ethiopia.

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A study was conducted to determine the response of potato (*Solanum tuberosum* L.) to different rates of nitrogen (N) applied as urea (0, 69, 138 and 207 kg/ha) and phosphorus (P) (0, 20, 40 and 60 kg/ ha) fertilization on Vertisols of Debre Berhan in the highlands of central Ethiopia. Application of 207 kg N/ha delayed days to flowering and physiological maturity by four and nine days, respectively compared to the control. Similarly, it increased plant height by 24 cm, above ground biomass by 224.5%, underground biomass by 108%, marketable tuber yield by 175%, total tuber yield by 119%, marketable tuber number by 95.6%, total tuber number by 34% and average tuber weight by 82% over the control. On the contrary, nitrogen fertilization significantly reduced tuber specific gravity and dry matter content without affecting stem number, unmarketable tuber yield and number, and harvest index. Application of 60 kg P/ha significantly increased days to flowering by two days, plant height by 10.5 cm, aboveground and underground biomass by 32 and 28% respectively, marketable tuber yield by 60%, and marketable tuber number by 43%. Other parameters such as days to physiological maturity, stem number, total tuber yield and number, unmarketable tuber yield and number, average tuber weight, specific gravity, dry matter content and harvest index were not significantly influenced by phosphorus fertilization. Total tuber yield was positively correlated with total tuber number (r = 0.60*), marketable tuber number (r = 0.87***) and average tuber weight (r = 0.81***) indicating that tuber yield increase in response to the fertilization was due to the increase both in tuber number and weight. It was observed that application of 138 kg N and 20 kg P/ha is required for optimum productivity of Gorebiella variety on the vertisols of Debere Berhan in the central highlands of Ethiopia under rain fed conditions.**

Key words: Debre Berhan, fertilizer, potato, quality, vertisols, yield.

INTRODUCTION

In terms of dry matter production per hectare, potatoes are among the most productive crops grown in the developing countries. Potato is a very important source of nutritious food for the different parts of the country. However, in central highlands of Ethiopia particularly in North Shewa since the soil is predominantly vertisols, its great potential has not been adequately exploited. Research work have indicated that potato could be one of the most important crops to be introduced in the area where the population experience recurrent malnutrition due to heavy dependence on cereal crops and poor crop productivity provided that appropriate agronomic practices are applied.

The average nutrient depletion in East Africa, particularly of Ethiopia is estimated to be around 47 – 88 kg/ha/year in general and 100 kg/ha/year in particular on the highlands (Henao and Baanante, 1999). Major factors contributing to such depletion are soil erosion, fixation of phosphorus and leaching in respect of nitrogen and potassium, further accelerated by deleterious land use practices resulting from high population pressure. Plants require a variety of elements for growth and development of which N, P, and K are the most important of the essential

*Corresponding author. E-mail: tekalightsegaw@yahoo.com. Tel.: 00251-915731357.

Table 1. Physical and chemical properties of the soil of the experimental site.

Parameter	Value
Texture	Clay
Total N	0.2%
Available P	5.4 ppm
Exchangeable K	1.5 meq/100 g
Ca	23.5 meq/100 g
Mg	11.0 meq/100 g
Cation Exchange Capacity	42.3 meq/100 g
pH	5.7
Organic matter content	4.35%
C/N ratio	18.8
Percentage base saturation	85.7%.

nutrients to plants because they are required in large quantities. The deficiency of these elements is manifested in the detrimental effects on the growth and development of the plants (Tisdale et al., 1995). Furthermore, high mobility of N and high affinity of P and K for chemical reactions and fixation in the soils solid phase put these plant nutrients on the priority list in soil fertility management studies (Kleinkopf et al., 1981).

In Ethiopia, the results of variety trials conducted over several locations on different crop species clearly indicated that soil nutrient stress is the most significant parameter controlling crop yield (Tamirie, 1989). Nevertheless, it is significant to note that fertilizer response is directly related to soil and crop types emphasizing that soils varying in fertility status and crop species respond differently to applied fertilizers. Low soil fertility is underlined as the critical problem among several production-limiting factors of the North Shewa area. The area is one of the oldest agricultural areas in Ethiopia and due to loss of soil fertility and shortage of land for grazing; it can now hardly support its population (Amare, 1978), thus necessitating external supply of inorganic and organic fertilizer inputs to increase crop productivity.

Potatoes respond well to the application of both farmyard manure and inorganic fertilizers. According to Bereke (1988), an application of 150 - 66 kg/ha of N-P_2O_5 under rain fed conditions resulted in a tuber yield advantage of 32% over the unfertilized control. An experiment conducted at Alemaya on clay soil indicated that application of 87 - 46 kg/ha of N-P_2O_5 is needed for optimum potato production (Getu, 1998). Application of 110-90 kg/ha of N-P_2O_5 was recommended for potato production on the black soil of Holetta (IAR, 2000). Hence, fertilizer requirement varies across locations due to many reasons such as difference in soil types, nutrient availability of the soil, economic factors of the area, moisture supply and variety.

Farmers in the study area are also conscious of the response of potato to applied nutrients and raise the crop in homesteads using farmyard manure and household garbage. They do not, however, know the type and rate of fertilizers to be applied for individual crop species and cultivars for improving crop productivity. Moreover, regardless of the fertility status of the soil and the types of cultivar, the blanket national recommendation of 165 kg/ha urea and 195 kg/ha Diammonium Phosphate (DAP) is being used for potato production in North Shewa. One of the major problems resulting in lower potato productivity in the zone is inadequate agronomic practice due to the lack of fertilizer rate recommendations based on the local conditions. To address this problem the study was initiated with the major objective of investigating the effects of different rates of N and P fertilization on the yield and yield components of potato grown on vertisols, central highland of Ethiopia.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Debre Berhan Research Center, (9^o 36' latitude, 39^o 38' longitude and altitude of 2780 m above sea level), which is located in central highland of Ethiopia. The experiment was conducted under rain fed condition, from June to October 2007. During the study period, the mean maximum temperature was 18.6°C (range 17.9 – 20.9°C) and minimum temperature was 8.2°C (range 5.4 - 9.6°C). In the same period, a total of 1045.5 mm precipitation was received and the mean relative humidity was 70.9% (range 58.4 – 80.3%). The field experiment was conducted on Vertisols and the physical and chemical properties of the soil are presented in Table 1.

Experimental treatments, design and procedures

Potato variety Gorebiella was used for the study. The treatments used consisted of the combinations of four levels of N (0, 69, 138 and 207 kg/ha) and four levels of P (0, 20, 40, and 60 kg/ha). The entire rate of P and the half rate of the N fertilizers were applied at the time of planting. The remaining half of the N was applied 45 days after planting. Urea (46% N) and Triple Super Phosphate, Triple Super Phosphate (46% P_2O_5) were used as fertilizer sources for N and P, respectively.

The design used was a 4 x 4 factorial experiment arranged in a Randomized Complete Block, replicated three times. The plot size was four rows of each 3 m long and medium size and well-sprouted potato tubers were planted at a spacing of 75 cm between rows and 30 cm between plants. Spacing between plots and replications were 1 and 1.5 m, respectively. Cultural practices such as weeding, cultivation and ridging were practiced as per the recommendation of the horticulture division of the Debre Berhan Research Center. To control late blight disease, Ridomil (3 g/l) was applied at weekly intervals since the incidence was observed.

Data collection

Days to flowering were recorded when 50% of the plant population attained the flowering stage. Plant height was determined by measuring height from the base of the main shoot to the apex at full blooming. Number of stems per hill was recorded as the average stem count of five hills per plot reached at flowering stage. Only stems arising from the mother tuber were considered as main stems. Above ground (stem and leaves) and underground (roots,

Table 2. Phenology and growth parameters of potato as affected by N and P application.

Treatment	Days to flowering	Days to physiological maturity	Stem number (per hill)	Plant height (cm)
		N fertilizer rates (kg N/ha)		
0	60.08d	104.83c	4.33	51.42d
69	61.17c	108.83b	4.47	65.76c
138	62.42b	110.25b	4.95	71.28b
207	63.92a	114.33a	4.93	75.74a
Level of significance	***	***	Ns	***
		P fertilizer rates (kg P/ha)		
0	60.75c	109.08	4.78	60.68b
20	61.58b	109.42	4.41	66.16a
40	62.33ab	109.00	4.97	66.20a
60	62.92a	110.75	4.53	71.17a
Level of significance	***	ns	ns	**
CV (%)	1.61	2.24	12.15	7.91

*Means of the same main effect within a column followed by the same letter are not significantly different at p > 0.05; ns = non significant, ** = significant at 1%, *** = Significant at 0.1%.

stolons, and tubers) biomass were recorded by taking the average dry biomass of three randomly selected plants six weeks after flowering (CIP, 1984). At this stage, the vines were still green but practically ceased growth. Samples were air dried and then oven dried at 72°C to constant mass.

Days to physiological maturity was recoded when the leaves of 70% of the plants in the plot turned yellowish. Tuber number and yield were represented by taking the average of 16 hills per plot. Healthy tuber with a size more than or equal to 50 g (weighed using sensitive balance) was considered marketable while rotten, diseased, insect attacked, deformed tuber and those having a weight less than 50 g was categorized as unmarketable. Average tuber fresh weight was recorded by dividing total fresh weight of tubers per plot by the total number of fresh tubers. Tuber specific gravity was measured using the weight in air and weight in water method (Kleinkopf et al., 1987). To determine, dry matter content tubers from five randomly selected plants per plot were washed, chopped and mixed and 200 g sample was taken and pre-dried at a temperature of 60℃ for 15 h and further dried for 3 h at 105℃ in a drying oven. It was calculated as the ratio between dry and fresh mass expressed as a percentage. Harvest index was determined as the ratio of fresh weight of tubers to the total biomass fresh weight at harvest.

Data analysis

All crop data were subjected to analyses of variance, using SAS statistical software (SAS, 1999) version 8.1. Means were separated using Student Newman Keuls (SNK) test. Simple linear correlations between parameters were computed when applicable.

RESULTS

Days to flowering and days to maturity

Nitrogen and P fertilization significantly influenced day required for flowering and to attain physiological maturity in potato (Table 2). Application of 207 kg N/ha delayed flowering and maturity by about 4 and 9 days, respectively as compared to the unfertilized treatment. Similarly, increasing P application from 0 to 60 kg P/ha prolonged the days to flowering by about 2 days. P fertilization did not significantly influence physiological maturity of Gorebiella variety (Table 2).

Nitrogen, P fertilization and their interaction did not significantly influence the number of stems initiated as presented in Table 2. On the contrary, N fertilization at a rate of 207 kg N/ha and P at 60 kg P/ha increased plant height by about 24 and 10.5 cm, respectively compared to the control.

Aboveground and underground biomass yields of potato found to be significantly influenced by N and P fertilezation (Table 3). As compared to the control, fertilized potato plants produced 224.5 and 32% more aboveground biomass yield in response to the application of 207 kg N and 60 kg P/ha, respectively. Similarly, the application of 207 kg N/ha increased the underground biomass yield by about 108% while application of 60 kg P/ha brought about 28% increase compared to the control (Table 3).

Without affecting the unmarketable component, N and P fertilization significantly influenced the productivity of potato measured in terms of marketable and total tuber yield (Table 4). Increasing N application from 0 to 207 kg N/ha brought about 176 and 119% marketable and total tuber yields increases, respectively. Similarly, application of 60 kg P/ha increased marketable and total tuber yield by about 66 and 50%, respectively over the control.

Nitrogen fertilization significantly increased both marketable and total tuber number without affecting the unmarketable one (Table 5). Application of 207 kg N/ha resulted in 95.6 and 33% more marketable and total tubers, respectively, as compared to the control. Application of P fertilizer significantly increased marketable tuber number without affecting the unmarketable and total tuber numbers. Application of 60 kg P/ha increased marketable tu-

Table 3. Above and underground biomass yield (g/hill) of potato as influenced by N and P application.

Treatment	Biomass yield (g/hill)	
	Above ground	Under ground
N fertilizer rates (kg N/ha)		
0	13.22c	135.97c
69	24.43b	202.02b
138	38.25a	228.68b
207	42.90a	283.13a
Level of significance	***	***
P fertilizer rates (kg P/ha)		
0	25.22b	185.47b
20	29.00ab	200.12ab
40	31.28ab	226.72ab
60	33.30a	237.53a
Level of significance	*	*
CV (%)	11.7	12.5

*Means of the same main effect within a column followed by the same letter are not significantly different at 5% of probability level (SNK test); * = Significant at 5%, *** = Significant at 0.1%.

Table 4. Marketable, unmarketable and total tuber yield (t/ha) of potato as influenced by N and P application.

Treatment	Tuber yield (t/ha)		
	Marketable	Unmarketable	Total
N fertilizer rates (kg N/ha)			
0	16.05c	6.50	22.55c
69	31.31b	4.07	35.37b
138	41.73a	4.74	46.47a
207	44.28a	5.12	49.40a
Level of significance	***	ns	***
P fertilizer rates (kg P/ha)			
0	24.81b	5.70	30.50b
20	32.19ab	5.43	37.05ab
40	35.08ab	4.85	40.50a
60	41.28a	4.45	45.72a
Level of significance	***	ns	***
CV	10.8	19.7	15.5

*Means of the same main effect within a column followed by the same letter are not significantly different at 5% of probability level (SNK test); ns= non significant, *** = Significant at 0.1%

ber number by 43.5% over the control.

Nitrogen treatment significantly increased tuber average weight but it decreased specific gravity and dry matter content while P and its interaction with N did not (Table 6). Average tuber weight progressively increased with increasing N rate up to 138 kg/ha and tended to decrease at the highest rate of 207 kg/ha. Increasing the application of N from 0 to 207 kg N/ha reduced specific gravity from 1.086 to 1.078 and dry matter content from 22.9 to 21.0%. Nitrogen and P fertilizer application as well as their interaction did not significantly affect the harvest index of potato (Table 6).

DISCUSSION

Several factors limiting crop yields have been reported by many workers. According to Downs and Hellmers (1975) and Tisdale et al. (1995), factors limiting crop yield (both in quantity as well as quality) can be categorized into four major headings: the soil upon which the crop grows, the

Table 5. The influence of N and P application on marketable, unmarketable and total tuber number (count/hill) of potato.

Treatment	Tuber number (count/hill)		
	Marketable	Unmarketable	Total
N fertilizer rates (kg N/ha)			
0	4.73c	6.76	11.49b
69	7.46b	4.67	12.13b
138	7.95ab	5.08	13.03b
207	9.25a	6.01	15.27a
Level of significance	***	ns	***
P fertilizer rates (kg P/ha)			
0	5.95b	6.15	12.10
20	7.12ab	5.30	12.42
40	7.784a	5.68	13.49
60	8.54a	5.38	13.92
Level of significance	***	ns	ns
CV (%)	13.7	19.3	10.0

*Means of the same main effect within a column followed by the same letter are not significantly different at 5% of probability level (SNK test), ns = non significant; *** = Significant at 0.1%

Table 6. Average tuber weight, tuber specific gravity, dry matter content and harvest index of potato as influenced by N and P application.

Treatment	Average tuber weight (g)	Specific gravity (g/cm^3)	Dry matter content (%)	Harvest index
N fertilizer rates (kg N/ha)				
0	44.28b	1.086a	22.96a	0.903
69	66.02a	1.085a	23.68a	0.887
138	74.69a	1.083a	22.88a	0.875
207	80.72a	1.078b	21.02b	0.854
Level of significance	***	***	***	ns
P fertilizer rates (kg P/ha)				
0	56.11	1.082	23.16	0.865
20	67.02	1.083	22.96	0.855
40	69.57	1.084	22.45	0.907
60	73.01	1.083	21.98	0.888
Level of significance	ns	ns	ns	ns
CV (%)	13.6	0.35	4.9	7.7

*Means of the same main effect within a column followed by the same letter are not significantly different at 5% of probability level (SNK test), ns = non significant; *** = Significant at 0.1%.

genetic make-up of the crop, the climatic conditions during the growth of the crop, and the management practices, mainly soil fertility. Maintaining adequate levels of soil fertility has been recognized as one of the management practices that affect growth, development and yield of plants (Tisdale et al., 1995).

Nitrogen fertilization delayed flowering and prolonged the time required by the potato crop to reach physiological maturity. This is in conformity with the findings of Lauer (1986) and Ojala et al. (1990) who observed that high N levels promoted excessive vegetative growth and delayed flowering. Low soil N is known to be a factor limiting potato production in Ethiopia and many parts of the world, especially when there is adequate water supply (Harris, 1992). Nitrogen fertilizer increased the leaf area which increases the amount of solar radiation intercepted and consequently, increases days to flowering, days to physiological maturity, plant height and dry matter production of different plant parts (Krishnippa, 1989).

The observations of the current investigation support previous studies on the effect of N and P on days to maturity (Wilcox and Hoff, 1970; Kleinkopf et al., 1987) where N and P nutrients are respectively reported to be associated with prolonging and shortening days to physiological maturity. In addition, Mulubrhan (2004) reported that N treatment significantly prolonged both the days to flowering and physiological maturity where as P application significantly accelerated physiological maturity.

Although stem density is one of the most important yield components in potato, it was not significantly influenced by both N and P fertilization. This could be due to the fact that the trait is much influenced by the inheritance of the potato crop. In agreement with the current study, different authors reported that stem number is determined very early in the ontogeny of plant (Lynch and Tai, 1989; De la Morena et al., 1994; Lynch and Rowberry, 1997). Stem number is not influenced much by mineral nutrients rather it is influenced by other factors such as storage condition of tubers, number of viable sprouts at planting, sprout damage at the time of planting and growing conditions (Allen, 1978), physiological age of the seed tuber (Iritani, 1968), variety (Lynch and Tai, 1989) and tuber size (Harris, 1978).

Plant height increase in response to the fertilization treatment may be attributed to stem elongation. Although there was differential response between varieties, N fertilization increased potato plant height (Yibekal, 1998). Positive and significant correlation (r = 0.61**) was observed between plant height and total tuber yield indicating the existence of positive association between the two parameters which corroborated the findings of Yibekal (1998).

Biomass yield increase in response to N and P fertilization indicates that both nutrients could exert a significant influence on biomass production and partitioning to the different parts. In this connection, Moorby and Morris (1967) reported that N plays a significant role in the production of stem and axillary branches. A significant increase in canopy dry matter yield in response to N fertilization is reported by Millard and Marshall (1986). Continuous supply of N to plants promote shoot and root growth while reducing tuberization in potato (Gunasena and Harris, 1969; Ivins and Bremner, 1969). Positive and highly significant correlation was obtained between above and underground biomass (r = 0.77***) indicating the existence of close association between them.

Nitrogen and P fertilization improved both the marketable and total tuber yield of potato. The observed higher fertilizer response may be linked to the increase in total leaf area which in turn increased the amount of solar radiation intercepted and more photoassimilate might have been produced and assimilated to the tubers. In this connection, Millard and Marshall (1986) reported that tuber yield improvement as a result of N fertilization could be attributed to increased radiation interception during the first part of the season and lower rates of decline in photosynthetic efficiency of the canopy during the later part. Kotsyuk (1995) also reported that fertilization increased leaf area, encouraged the formation of many tubers, and increased duration of tuber bulking. Higher yield response with increasing the levels of both fertilizer types indicate the importance of higher rates of N and P fertilizers to obtain higher marketable yield. Potato tuber yield is directly dependent on the supply of N, K and P, though excessive supply of N may substantially delay leaf senescence leading to enhanced leaf area duration and increased tuber yield (MacKerron and Heilbronn, 1985). The unmarketable tuber yield was not significantly affected by the different N and P rates. It is more important to control it through manipulating other factors such as disease incidence, harvesting practices, etc, rather than mineral nutrition (Berga et al., 1994).

N fertilizer is reported to affect yield by its effect on the number of tubers produced per plant, the average weight of tubers, the establishment and leaf area duration (Wilcox and Hoff, 1970). Timm and Flocker (1966) observed optimum tuber yield when N fertilizer was applied at the rate of 204 kg/ha and yield reduction was noted when applied above this rate. In the current experiment, N application beyond 138 kg/ha did not bring significant yield advantage. The yield reduction due to excess rates of N may be explained by the fact that excessive N application stimulates shoot growth more than tuber growth which may result in deterioration of canopy structure and physiological conditions (Som-merfeld and Knutson, 1965).

Potato tuber yield is also known to be influenced by P fertilizers through its effect on the number of tubers produced, the size of the tubers and the time at which maximum yield is obtained (Sommerfeld and Knutson, 1965; Sharma and Arora, 1987). They showed that yield response to increasing levels of P fertilizer was generally positive up to a particular level, above which the response became negative. They also noted that excess use of P fertilizers is usually associated with reduced tuber weight by hastening the maturation period and reducing tuber size. Applied P has been found to increase the yield of small and medium size tubers (Hanley et al., 1965; Sommerfeld and Knutson, 1965). Though P had a positive effect on tuber yield, the percentage of yield increase due to P was smaller than the yield increase due to N. This could probably be explained by the fact that P leads to faster closure of canopy and shorten the growing period (Sommerfeld and Knutson, 1965). The other possible reason is that applied P may not be available to the plants at a rate similar to N fertilizer because of problem of soil fixation to satisfy first the soil demand of P.

Days to physiological maturity were positively and significantly correlated with marketable (r = 0.56**) and total tuber yield (r = 0.56**) suggesting that delaying the maturity period in response to the fertilization treatment substantially contributed for tuber yield increase probably due to more assimilate production and bulking. Addition of N ensures maintenance of photosynthetically active leaves for longer duration and the formation of new leaves than with lower or no N supply (Millard and Marshall, 1986).

The observed tuber number increase in response to N fertilization could be attributed to an increase in stolon number through its effect on Gibberellins biosynthesis in the potato plant. The involvement of gibberellins in regulating stolon number through stolon initiation is reported by Kumar and Wareing (1972). According to Amzallag et al. (1992), N affect tuber formation in potato by influencing the activity and phytohormone balance in the plant, especially, on the levels of gibberellic and abscissic acids and cytokinins. Nitrogen application to potatoes before tuber initiation increases the number of tubers per plant and mean fresh tuber weight (Kanzikwera et al., 2001). In agreement with the present finding, various researchers reported significant tuber number increase in response to N application (Sommerfeld and Knutson, 1965; Gunasena and Harris, 1969; Sparrow et al., 1992, Lynch and Rowberry, 1997). On the contrary, however, there are reports indicating the absence of strong relationship between rates of N application and tuber number in potato (Sharma and Arora, 1987; De la Morena et al., 1994). Total tuber yield found to be strongly associated with average tuber weight (r = 0.81***) and total tuber number (r = 0.60***) signifying both the increase in tuber number as well as size have substantially contributed to tuber yield increase in response to the fertilization treatments.

Phosphorus fertilization did not influence significantly total tuber number. Contradicting results have been reported regarding the effects of P and K on the tuber number that may be linked to the difference in season, inherent nutrient status of a soil and location which could have exerted their effects in determining the number set by the potato plant. Tuber number is not an important yield limiting component while studying mineral nutrition (Sharma and Arora, 1987; De la Morena et al., 1994; Lynch and Rowberry, 1997) that could be due to the inverse association between tuber number and average tuber weight (De La Morena et al., 1994).

The results showed that N and P fertilization is required to maximize tuber weight which is known to significantly influence the productivity of the potato crop. In agreement with the present finding, Sharma and Arora (1987), De la Morena et al. (1994) and Bereke (1994) reported a significant increase in average tuber weight in response to N application. Similarly, Harris (1978), Giardini (1992) and De La Morena et al. (1994) reported that yield increase due to mineral nutrition was attributed to its effect on average tuber weight. The increase in average tuber weight of tubers in response to the increased supply of fertilizer nutrients could be due to more luxuriant growth, more foliage and leaf area and higher supply of photosynthates which may have induced formation of bigger tubers thereby resulting in higher yields (Patricia and Bansal, 1999). However, contrary to the present results, non-significant response in average tuber weight was evident when P treatment rates were increased (Bereke, 1994)

Specific gravity of raw potatoes is widely accepted by the potato processing industry as a measure of total solids, starch content and other qualities. High, uniform specific gravity in potato tubers is important to the grower and the processor. Nitrogen fertilization significantly reduced both tuber specific gravity and dry matter content which may be associated with the influence of N on gibberellins biosynthesis and other phytohormonal activities which have direct influence on plant growth and dry matter accumulation. High levels of endogenous GA delay or inhibit tuberization (Abdella et al., 1995), and impede the accumulation of starch, patatin and other tuber specific proteins (Vreugdenhil and Sergeeva, 1999). In favour of the current finding, Painter and Augustine (1976) and Kleinkopf et al. (1981) reported that the specific gravity of tubers decreased with increasing rates of N fertilizer. The depressive effect of applied N on tuber dry matter was also confirmed by Cole (1975) and Kleinkopf et al. (1981), whereby tuber dry matter decreased with increased N application. Contrary to this, Roberts and Cheng (1988) noted non-significant difference in specific gravity of tubers due to N treatment.

Phosphorus fertilization did not significantly influence tuber specific gravity and dry matter content. Conflicting results have been reported regarding the effect of P fertilization on tuber specific gravity of potato. Human (1961) noted an increase in specific gravity in response to an increase in applied P. On the contrary, Sparrow et al. (1992) observed non-significant reduction in percent dry matter of tubers due to increased P application. The absence of strong relationship between P application and specific gravity was reported by Zandstra et al. (1969) and Dubetz (1975). In this study, it is proved that specific gravity is strongly and positively correlated with dry matter content (r = 0.92**) indication that the former is an excellent indicator of the latter which agrees with the report of Tekalign and Hammes (2005).

Although it is not consistent and statistically significant, there was a decreasing trend in harvest index in response to increasing N fertilization while P fertilization showed an increasing trend. This may be attributed to an increased haulm growth in response to N treatment. Increasing N fertilization increased partitioning of assimilates to the shoots rather than to the tubers (Biemond and Vos, 1992). Similar to the short term effects of short photoperiods, withholding N fertilization increased starch content of the leaves, increased the percentage export of assimilates from the leaves, and reduced the activity of sucrose phosphate synthase (Oparka et al., 1987). Nitrogen application increased aboveground biomass yield of potato (Millard and Marshall, 1986). In the present study weak negative relationship ($r = -0.17^{ns}$) was observed between harvest index and total tuber yield. In general, this study indicated that although harvest index is a measure of the proportion assimilates partitioned to harvested organs and used by plant physiologists and breeders in the selection of high yielding cultivars, high harvest index may not necessarily correlate with high yield (Gawronska et al., 1984). This implies that a cultivar with low harvest index may not necessarily be low yielder. This is possible where a cultivar is able to produce high rate of carbon assimilates and maintains active growth later in the season thereby giving high yield in spite of the harvest index value.

This study indicates that yield and yield components of the potato variety Gorebiella can be improved with the application of N and P fertilizers in Debere Berhan areas of central Ethiopia. Hence, application of 138 kg N and 20 kg P/ha is found to be the appropriate rates for optimum productivity of Gorebiella variety on the vertisols of Debere Berhan in the central highlands of Ethiopia under rain fed conditions.

REFERENCES

Abdella G, Guinazu M, Tizio R, Pearce DW, Pharis RP (1995). Effect of chloroethyl trimethyl ammonium chlorides on tuberisation and endogenous GA3 in roots of potato cuttings. Plant Growth Regul. 17: 95-100.

Allen EJ (1978). Plant density. In: Harris PM (ed) The Potato Crop: The Scientific Basis for Improvement, pp. 279-324.

Amare G (1978). Cropping systems in Africa: The Ethiopian Case: Proceeding of the Workshop on Cropping Systems in Africa held at Morogoro, Tanzania, pp. 35-44.

Amzallag GN, Herner HR, Poljakott-Mayber A (1992). Interaction between mineral nutrients, cytokinin and gibberellic acid during growth of sorghum at high NaCl salinity. J. Exp. Bot. 43: 81-87.

Bereke TT (1988). Potato research and future improvement prospects in Ethiopia: Proceedings of the 19th National Crop Improvement Conference held in Addis Ababa, Ethiopia, pp. 301-310.

Berga L, Gebremedhin W, Terrisa J, Bereke TT, Yaynu H (1994). Potato improvement research. In: Edward H, Lemma D (eds). Proceedings of the Second National Horticultural Workshop of Ethiopia held in Addis Ababa, Ethiopia.

Biemond H, Vos J (1992). Effects of nitrogen on the development and growth of potato plant. 2. The partitioning of dry matter, nitrogen and nitrate. Ann. Bot. 70: 37-45.

CIP (International Potato Center) (1984). Potato for the developing world. Lima, Peru. 150 P.

Cole SC (1975). Variation in dry matter between and within potato tubers. Potato Res. 18: 28-37.

De la Morena I, Guillen A, Garcia del Morel LF (1994). Yield development in potatoes as influenced by cultivar and the timing and level of nitrogen fertilizer. Am. Potato. J. 71: 165-173.

Downs RJ, Hellmers H (1975). Experiment and the experimental control of plant growth. Academic press, New York, pp. 135-178.

Dubetz S. (1975). Effect of two depths of seedbed preparation and fertilizer on netted gem potatoes. Am. Potato. J. 52: 263-267.

Gawronska H, Duelle RB, Pavek JJ, Rowe P. (1984). Partitioning of photo-assimilates by four potato (*Solanum tuberosum* L.) clones. Crop. Sci. 24: 1031-1036.

Getu B. (1998). Yield, quality and nitrogen uptake of potato (*Solanum tuberosum* L.) as influenced by rate and time of nitrogen application. M.Sc. Thesis, Alemaya University, Ethiopia.

Giardini L. (1992). Effects of poultry manure and mineral fertilizers on the yield of crops. J. Agri. Sci. 118: 207-213.

Gunasena HPM, Harris PM (1969). The effects of CCC and nitrogen on the growth and yield of the second early potato variety, Craig's Royal. J. Agri. Sci. 73: 245-259.

Hanley F, Jarvis RH, Ridgman WJ (1965). The effects of fertilizers on the bulking of Majestic Potatoes. J. Agri. Sci. 65: 159-169.

Harris PM (1978). Mineral Nutrition. In: Harris PM (ed) The potato Crop: The Scientific Basis for Improvement. Champman and Hall, London, pp. 195-243.

Harris PM (1992). Mineral Nutrition. In: Harris PM (ed) The potato Crop: The Scientific Basis for Improvement. Chapman and Hall, London, pp. 162-209.

Henao J, Baanante C (1999). Estimating rates of nutrient depletion in soils of agricultural lands of Africa. International Fertilizer Development Center (IFDC). Musck Shoals, Alabama, USA, p. 76 .

Human JJ (1961). The effect of fertilizer levels on yield and specific gravity of potatoes. Biological Abstract 39: 278.

IAR (Institute of Agricultural Research). 2000. Holetta Guenet Research Station Progress Report, Addis Ababa, Ethiopia.

Iritani WM (1968). Factors affecting physiological ageing (degeneration) of potato tubers used as seed. Am. Potato. J. 45: 111-116.

Ivins JD, Bremner PM (1969). Growth, development and yield in the potato. Outlook on Agri. 4: 211-217.

Kanzikwera RC, Tenywa JS, Osiru DSO, Adipala E, Bhagsari AS (2001). Interactive effect of nitrogen and potassium on dry matter and nutrient partitioning in true potato seed mother plants. Afri. Crop. Sci. J. 9:127-146.

Kleinkopf GE, Westermann DT, Duelle RB (1981). Dry matter production and nitrogen utilization by six potato cultivars. Agron. J. 73: 799-802.

Kleinkopf GE, Westermann DT, Wille MJ, Kleinscmidt GD (1987). Specific Gravity of Russet Burbank Potatoes. Am. Potato J. 64: 579-587.

Kotsyuk VI (1995). Using statistical methods for estimating the effect of fertilizers on potato productivity in the kol'skoi subaritic region. Agrokhinya 12: 76-88.

Krishnippa KS (1989). Effect of fertilizer applications on dry matter and N, P, and K accumulation in the potato at different stages of growth. Mysore J. Agri. Sci. 23:349-354.

Kumar D, Wareing PF (1972). Factor controlling stolon development in potato plant. New Phytology 71: 639-648.

Lauer DA (1986). Response of Nooksack potatoes to nitrogen fertilizer. Am. Potato. J. 63:251-262.

Lynch DR, Rowberry RG (1997). Population density studies with Russet Burbank potatoes. II. The effect of fertilization and plant density on growth, development, and yield. Am. Potato. J. 54: 57-71.

Lynch DR, Tai GC (1989). Yield and yield component response of eight potato genotypes to water stress. Crop Sci. 29: 1207-1211.

MacKerron DKL, Heilbronn TD (1985). A method for estimating harvest indices for use in surveys of potato crops. Potato Res. 28:279-82.

Millard P, Marshall B (1986). Growth, nitrogen uptake and partitioning within the potato crop (*Solanum tuberosum* L.) in relation to nitrogen application. J. Agri. Sci. 107: 421 - 429

Moorby J, Morris DA (1967). Inter-stem and inter-tuber competition in potatoes. Euro. Potato. J. 10:189-205.

Mulubrhan H (2004). The effect of Nitrogen, Phosphorus and Potassium fertilization on the yield and yield components of potato (*Solanum tuberosum* L.) grown on vertisols of Mekele area. M.Sc. Thesis. Haramaya University, Ethiopia, p. 24 .

Ojala JC, Stark J, Kleinkopf GE (1990). Influence of irrigation and nitrogen management on potato yield and quality. Am. Potato. J. 67:29-44

Oparka KJ, Davies HV, Prior DAM (1987). The influence of applied nitrogen on export and partitioning of current assimilate by field grown potato plants. Ann. Bot. 59: 311-323.

Painter CG and Augustine J (1976). The effects of soil moisture and nitrogen on yield and quality of the Russet Burbank Potato. Am. Potato. J. 53: 275-284.

Patricia I, Bansal SK (1999). Potassium and integrated nutrient management in potato. A paper presented at the Global Conference on Potato, 6-11 December 1999, New Delhi, India.

Roberts S, Cheng HH (1988). Estimation of critical nutrient range of petiole nitrate for sprinkler irrigated potatoes. Am. Potato. J. 65: 119 – 124.

SAS Institute (1999). SAS statistical guide for personal computers, version 8.1.

Sharma VC, Arora BR (1987). Effects of nitrogen, phosphorus, and potassium application on the yield of potato tubers (*Solanum tuberosum* L.). J. Agri. Sci. 108: 321-329.

Sommerfeld TG, Knutson KW (1965). Effects of nitrogen and phosphorrus on the growth and development of Russet Burbank Potatoes grown in the Southeastern Idaho. Am. Potato. J. 42: 351-360.

Sparrow LA, Chapman KSR, Parsley D, Hardman PR, Cullen B (1992). Response of potatoes (*Solanum tuberosum* L. cv. Burbank) to band placed and broadcast high cadmium phosphorus fertilizer on heavily cropped Krasnozems in North-Western Tasmania. Aust. J. Exp. Agri. 32: 113 – 119.

Tamirie H (1989). Increasing Agricultural Production through improved soil, water and crop Management practices. In the proceedings of the national workshop on food strategies for Ethiopian held at Alemaya University of Agriculture 8-12 December 1986, Ethiopia. pp. 243-275

Tekalign T, Hammes PS (2005). Response of potato grown in a hot tropical lowland to applied paclobutrazol. II: Tuber attributes. New Zealand J. Crop. Hort. Sci. 33:43-51.

Timm H, Flocker WJ (1966). Response of potato plants to fertilization and soil moisture tension under induced soil compaction. Agron. J. 77: 616-621.

Tisdale SL, Nelson WL, Beaton JD, Halvin JL (1995). Soil Fertility and Fertilizers (5^{th} Ed.), Macmillan Publishing Co., Inc. New York, pp. 109-229.

Vreugdenhil D, Sergeeva LI (1999). Gibberellins and tuberisation in potato. Potato. Res. 42: 471– 481.

Wilcox GE, Hoff J (1970). Nitrogen fertilization of potatoes for early summer harvest. Am. Potato. J. 47: 99-102

Yibekal A (1998). Effects of Nitrogen and phosphorus on yield and yield components, and. some quality traits of potato (*Solanum tuberosum* L.) at Wondo Genet area. M.Sc Thesis, Alemaya University of Agriculture, Ethiopia, p. 82.

Zandstra HG, Anderson RH, Daley WK (1969). Effects of fertilizer on the yield and quality of Norland Potatoes in Northeastern Saskatchewan. Am. Potato. J. 46: 69-74